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Real exchange rates between the wars

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Bilateral real exchange rates are analyzed for fifteen countries over the period 1925–1937, using a benchmark-invariant principal components technique. For the period 1925–1931, half of real exchange rate variation originates from countries on floating exchange rates, and half from price level differences between countries on the gold standard. For the period 1931–1937, real exchange rate movements between the sterling-bloc, the European gold-bloc, and the US and Canada appear dominant. Within bloc variation is secondary and mostly due to competitive devaluations. Our results support earlier evidence that the nominal exchange rate regime to a large extent determines real exchange rate variation. (JEL F31). © 1997 Elsevier Science Ltd.

The level and variability of bilateral real exchange rates have been the subject of study for a long time. Important issues in this respect are the magnitude and persistence of real exchange rate deviations from equilibrium, the validity of relative purchasing power parity (PPP) in the short or long run[1] and the role of the real exchange rate in promoting external equilibrium.

In this context, it has often been argued that the behavior of real exchange rates depends on the nominal exchange rate regime to a large extent (see Stockman (1983), and Grilli and Kaminsky (1991) for an overview). Fisher (1934) already notes that countries on the same monetary standard have similar price movements while countries not on the same monetary standard do

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not. This suggests low real exchange rate variability among countries on fixed exchange rates. In the same vein, Mussa (1986), for example, claims that the variance of the real exchange rates of the major industrialized countries is eight to eighty times higher during periods of floating exchange rates than during periods of fixed exchange rates. For the interwar period, Eichengreen (1990) shows for a set of nine countries that on average real exchange rate variability was highest in the interwar floating period (1922–1926), and lowest under the gold-exchange standard (1927–1931), with the managed floating period (1932–1936) falling in between.[2]

One explanation for this phenomenon would be that under floating exchange rates and sticky goods prices, nominal exchange rate changes are almost one-to-one reflected in real exchange rates, while under fixed nominal exchange rates, real exchange rates could remain relatively stable. Arguments advanced by Eichengreen (1990, 1992) and Nurkse (1944), on the other hand, suggest that under the gold exchange standard (1925–1931), sizable real exchange rate changes occurred too, because of large over- or undervaluations of the nominal exchange rate. This would require correspondingly strong domestic inflations or deflations.

Grilli and Kaminsky (1991) challenge the conventional wisdom that real exchange rate variability depends on the nominal exchange rate regime. They cannot reject the hypothesis that dollar–pound real exchange rate movements across regimes in the interwar period come from a common distribution and suggest that real exchange rate variability may depend on specific historic events, and, thus, is sample specific.

In this paper, we intend to add to and improve on the existing evidence on interwar real exchange rate behavior. First, we apply a principal components procedure to extract the dominant factors from a set of bilateral real exchange rates between 15 currencies.[3] A modification of the standard procedure is needed to make the set of extracted principal components invariant to the arbitrary choice of benchmark currency. The major advantage of the technique is that it allows for a simultaneous and symmetric analysis of all bilateral real exchange rates in our data set. In the literature, a more asymmetric view is taken in general, with exchange rates being expressed in US dollars (or UK pounds) only. Second, we explicitly study and compare the gold-exchange period (1925–1931) and the managed floating period (1931–1937) to investigate the influence of a change in the nominal exchange rate regime on real exchange rate patterns.

The paper is organized as follows. In Section I we derive the benchmark-invariant principal components transformation. In Section II, the data are described. In Section III, we present and discuss the results of the principal components analysis for our data set of 15 countries over the periods May 1925 to August 1931 (gold exchange standard), and September 1931 to December 1937 (managed floating). Section IV contains our conclusions.

I. Methodology: principal components

Principal components analysis[4] is a powerful instrument to extract (a few) dominant factors from a large set of time series. However, in a standard principal components analysis of real exchange rates the arbitrary choice of a benchmark currency affects the component structure. The correlation matrix of exchange rates vis-à-vis the dollar produces a different set of principal components than the correlation matrix of D-mark exchange rates, although they contain exactly the same amount of information.

To overcome this problem we require the set of principal components to be invariant with respect to the choice of benchmark currency. The cross sectional relations between exchange rates provide useful prior information to obtain a unique scaling of the exchange rate data which will ensure such invariance property in a natural and intuitive way.

Consider an $(n \times 1)$ multivariate time series $\{x_t\}_{t=1}^{T}$ of logarithms of real exchange rates expressed in a common benchmark currency. Observations on $\{x_t\}$ are stored in the $(T \times n)$ data matrix X. The $(T \times n)$ matrix Z of principal components is a transformation of the data matrix X, such that:

1. $Z = XQB$, with Q positive definite symmetric and B non-singular;
2. $Z'Z = \Lambda$, with Λ a diagonal matrix with elements $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_n \geq 0$;
3. $B'QB = I$, a normalization.

Condition 1 shows that the transformation $X \to Z$ is linear. Q is an $(n \times n)$ scaling matrix and B is an $(n \times n)$ matrix containing the so-called factor loadings. The second condition requires the components to be orthogonal. Λ is an $(n \times n)$ diagonal matrix. The elements of Λ are in descending order of magnitude and determine the variance of the principal components. The first principal component (the first column of Z) has the largest variance. Condition 3 is a normalization to set the scale of Z.

The transformation from X to Z is unique once Q has been specified, i.e. there exists only one matrix B satisfying conditions 1, 2 and 3[5] (see Leamer 1978, Appendix A, theorem 35). Given Q, the principal components may be computed through solving the eigenvalue problem:

$$\langle 1 \rangle \qquad (Q^{1/2}X'XQ^{1/2})(Q^{1/2}B) = (Q^{1/2}B)\Lambda$$

where $Q^{1/2}Q^{1/2} = Q$. Equation $\langle 1 \rangle$ shows how the components depend on the choice of the scaling matrix $Q^{1/2}$. Q is not determined in the principal component analysis, but must be specified a priori by the user.

In many principal components applications, scale dependence problems exist. If one of the variables has a much larger variance than the others, for instance because of having a different dimension, it will generally dominate the first principal component. For this reason, the analysis is mostly performed on normalized variables. In that case, the matrix Q is chosen diagonal with elements $q_{ii} = 1/s_{ii}$, where s_{ii} is the sample variance of $\{x_{it}\}$. Then, the only data input to the principal component analysis is the sample correlation matrix.

The issue of scale dependency plays no role here, however. First, all variables in our data set have the same dimension of a number of foreign currency units per unit of some benchmark currency. Second, we have selected only countries without excessive inflation or exchange rate movements. We will choose Q such that the components Z are invariant to a change in the benchmark currency.

To find a suitable matrix Q, we first look at the effect of a change in the benchmark currency. Let x_{kj} be the logarithm of the (real) exchange rate of currency j against the benchmark currency k. Letting currency i be the benchmark instead of currency k amounts to the linear transformation:

$$\langle 2\rangle \qquad \begin{aligned} x_{ij} &= x_{kj} - x_{ki}, \qquad \text{for } j \neq k; \\ x_{ik} &= -x_{ki}. \end{aligned}$$

The transformation can be written compactly in matrix notation as

$$\langle 3\rangle \qquad x^1 = Px^0,$$

where P is the $(n \times n)$ matrix:

$$\langle 4\rangle \qquad P = \begin{pmatrix} -1 & 0' \\ -\iota_{n-1} & I_{n-1} \end{pmatrix}$$

in which ι is a unity vector[6] (here of length $n-1$), I is the identity matrix, x^0 is an $(n \times 1)$ vector of exchange rates in the original benchmark currency, and x^1 is the vector of exchange rates in the new benchmark currency (in this case currency). For notational convenience we have re-arranged the order of exchange rates such that currency became the new benchmark. Transformation to another benchmark currency, say currency k, entails a permutation of the rows and columns of P. An important property of P is that it is unipotent, meaning that $P^2 = I$. Applying the same transformation twice yields the original exchange rates.

Let X_i and X_k be the $(T \times n)$ matrices of observations on log exchange rates expressed in currency i and k, respectively. A change of the benchmark implies that the data matrix X_i is post-multiplied by P' (after the necessary permutation of columns and rows in P', or of the columns in X_i and X_k). The principal components (Z) are invariant to this change of benchmark currency if:

$$\langle 5\rangle \qquad X_i Q B_i = Z = X_k Q B_k.$$

Using the unipotent transformation matrix P in $\langle 4\rangle$, we can write:

$$\langle 6\rangle \qquad X_i Q B_i = X_k (P'QP) P B_i.$$

A comparison of equations $\langle 5\rangle$ and $\langle 6\rangle$ shows that the principal components will be invariant to the change in the benchmark if we can construct Q such that $Q = P'QP$, and if the factor loadings are related by $B_k = PB_i$. Moreover, these conditions must hold for all possible benchmark currencies, i.e. all permutations of the transformation matrix P. Partitioning Q^{-1} and expanding the condition $Q = P'QP$ yields:

$$\langle 7\rangle \qquad Q^{-1} = \begin{pmatrix} q^{11} & q^{12} \\ q^{21} & Q^{22} \end{pmatrix} = \begin{pmatrix} -1 & 0' \\ -\iota & I \end{pmatrix} \begin{pmatrix} q^{11} & q^{12} \\ q^{21} & Q^{22} \end{pmatrix} \begin{pmatrix} -1 & -\iota' \\ 0 & I \end{pmatrix}$$
$$= \begin{pmatrix} q^{11} & q^{11}\iota' - q^{12} \\ q^{11}\iota - q^{21} & q^{11}\iota\iota' - q^{21}\iota' - \iota q^{12} + Q^{22} \end{pmatrix},$$

where q^{11} is a scalar, q^{12} and q^{21} are $(n-1)$ vectors, Q^{22} is a $[(n-1)\times(n-1)]$ matrix. From equation ⟨7⟩ we obtain the restrictions:

$$\langle 8\rangle \qquad q^{21}=\frac{q^{11}}{2}\iota, \qquad \text{and} \qquad q^{12}=\frac{q^{11}}{2}\iota'$$

All non-diagonal elements in the first row and column of Q^{-1} must be equal and half the diagonal element. Since this must also hold if columns and rows 1 and j ($j=2,\ldots,n$) are interchanged, the restrictions in ⟨8⟩ must hold for all columns and rows. Hence the matrix Q^{-1} has the structure:

$$\langle 9\rangle \qquad Q^{-1}=\theta(I_n+\iota_n\iota'_n),$$

where θ is an arbitrary scalar.[7] The matrix inversion lemma then implies:

$$\langle 10\rangle \qquad Q=\frac{1}{\theta}\left(I-\frac{1}{n+1}\iota\iota'\right)=[\theta^{-1/2}(I-\alpha\iota\iota')]^2=(Q^{1/2})^2$$

for[8] $\alpha=(1-(n+1)^{-1/2})/n$. It remains to be verified that $B_k=PB_i$ relates the new factor loadings to the old factor loadings. To prove this, we need condition 2 in the definition of the principal components. The factor loadings are uniquely determined by the requirement that the principal components are orthogonal with decreasing variances, which appear on the diagonal of the Λ:

$$\langle 11\rangle \qquad \Lambda_i=B'_iQX'_iX_iQB_i=(B'_iP')(P'QP)(PX'_iX_iP')(P'QP)(PB_i)$$
$$=\left(B'_iP'Q^{1/2}\right)\left(Q^{1/2}X'_kX_kQ^{1/2}\right)\left(Q^{1/2}PB_i\right).$$

But B_k and Λ_k are also uniquely determined in

$$\langle 12\rangle \qquad \Lambda_k=B'_kQX'_kX_kQB_k=\left(B'_kQ^{1/2}\right)\left(Q^{1/2}X'_kX_kQ^{1/2}\right)\left(Q^{1/2}B_k\right).$$

Conditions ⟨11⟩ and ⟨12⟩ define the same eigenvalue problem, since $(Q^{1/2}PB_i)$ and $Q^{1/2}B_k$ are both required to be orthogonal matrices in condition 3 of the definition of the principal components. Therefore, $B_k=PB_i$, and $\Lambda_k=\Lambda_i$. This completes the proof that there exists a unique set of benchmark-invariant principal components.

If all n components are extracted from the original series the transformation is non-singular and no information in the data is lost. The proportion of total variation in the data explained by the first K components is expressed by the goodness-of-fit statistic (see Anderson, 1984):

$$\langle 13\rangle \qquad R^2(K)=\frac{tr(Z(K)'Z(K))}{tr(Q^{1/2}X'XQ^{1/2})}=\frac{\sum_{i=1}^{K}\lambda_i}{\sum_{i=1}^{n}\lambda_i},$$

where $\lambda_1>\lambda_2>\ldots>\lambda_n$ are the eigenvalues of $(Q^{1/2}X'XQ^{1/2})$, and $Z(K)$ is the $(T\times K)$ matrix of the first K principal components of the transformed data $XQ^{1/2}$.

For the interpretation of the components our interest is in the correlation between component 1 and a time series of real exchange rate x_{ij}. Since the principal components are orthogonal, the total amount of variation in x_{ij} explained by the first K components is the sum of the squared correlations:

$$\langle 14 \rangle \qquad R_{ij}^2(K) = \sum_{l=1}^{K} r_{ij}^2(l),$$

where $r_{ij}^2(1)$ is the squared correlation between x_{ij} and component 1.

The principal component analysis is largely descriptive and only allows for identification of groups of countries with similar real exchange rate behavior. Formal hypothesis testing is as yet infeasible. In our analysis, we will focus on a comparison of individual correlations $r_{ij}^2(1)$ with the overall fit measured by $\lambda_1/\Sigma_{i=1}^n \lambda_i$, therefore. We will concentrate on those correlations exceeding the average fit. If a number of real exchange rates is highly, that is, above average, correlated with some principal component, we identify this component with that group of currencies.

II. Data

The following 15 countries have been selected for the principal component analysis: Belgium (BE), the Netherlands (NL), Germany (GE), France (FR), the United Kingdom (UK), Czechoslovakia (CS), the United States (US), Denmark (DK), Sweden (SW), Norway (NW), Switzerland (CH), Italy (IT), Finland (SF), Japan (JP) and Canada (CA). Nominal exchange rates and wholesale price indices have been taken from the League of Nations Monetary Review, for the sample period 1925:5 to 1937:12 (monthly data).[9] All variables have been transformed to logarithms. Real exchange rates against the US dollar were constructed as $x = e - p + p^{US}$, where e is the log nominal exchange rate, p is the log of the wholesale price index and p^{US} denotes the log of the US wholesale price index.

In Table 1 means and standard deviations for bilateral real exchange rates against the US dollar (in logarithms) over the two sub periods 1925:5–1931:8 and 1931:9–1937:12 are presented. Also the standard deviations of bilateral real exchange rates relative to the pound are shown for these two periods. The table offers the familiar picture that standard deviations surge in the second period. Although this holds true both for \$ and £ real exchange rates, it is clear that the extent to which the variability changes across sub periods does depend on the choice of benchmark currency.

Figure 1 contains a graphical presentation of real exchange rates against the dollar for each country (solid lines, left scale). Additionally, the difference between the domestic and US price level is shown (dotted lines, right scale). One message emerging from these graphs is that indeed groups of countries display similar real exchange rate behavior against the dollar. One easily defined group, for instance, is the so-called sterling-bloc (the United Kingdom, Denmark, Norway, Sweden, Finland, and Canada).[10] These countries' real exchange rates show remarkably similar peaks and troughs in the early thirties. Another group is the gold-bloc (the Netherlands, Germany, France, Italy, Switzerland and Czechoslovakia), which also exhibit a common pattern in the thirties.

TABLE 1. Summary statistics of real exchange rates (logarithms, relative to the US \$ and the UK £)

Country	1925:5–1931:8 Mean (\$)	S.D. (\$)	S.D. (£)	1931:9–1937:12 Mean (\$)	S.D. (\$)	S.D. (£)
NL	0.53	0.052	0.041	0.45	0.162	0.117
GE	1.08	0.036	0.054	0.82	0.150	0.103
BE	1.41	0.034	0.039	1.37	0.093	0.109
FR	1.38	0.052	0.057	1.25	0.109	0.105
UK	−1.95	0.031	—	−1.88	0.111	—
IT	1.35	0.057	0.056	1.24	0.144	0.148
CH	1.24	0.024	0.026	1.10	0.122	0.141
SW	0.91	0.033	0.025	1.01	0.101	0.082
DK	0.87	0.031	0.020	0.97	0.091	0.086
NW	0.81	0.035	0.039	0.93	0.102	0.083
CS	1.24	0.044	0.043	1.07	0.101	0.144
JP	0.21	0.036	0.029	0.61	0.123	0.144
CA	−0.45	0.018	0.038	−0.38	0.037	0.088
SF	3.29	0.044	0.055	3.35	0.084	0.096
US	—	—	0.031	—	—	0.111

III. Partitioning real exchange rates

The principal objective of this article is to find empirical regularities in the behavior of real exchange rates between 1925 and 1937. We will investigate how the results depend on the choice of sample period by comparing the managed gold standard period (1925:5–1931:8) with the interwar managed floating period (1931:9–1937:2). May 1925 is chosen as the starting point because of Britain's return to gold at the pre-war parity in April. Correspondingly, the end point of the first period (August 1931) and the start of the second one (September 1931) is set at the moment the United Kingdom suspended gold convertibility and left the gold standard. These choices are in line with the literature, see for example Grilli and Kaminsky (1991) and Eichengreen (1990, 1992).

Obviously, the choice of sub periods may influence the results, particularly so, because individual countries in the sample entered and left the gold exchange standard at different times. Moreover, transitional problems in the switch from one regime to another could well have an additional effect on real exchange rate variability. In our discussion, we will pay explicit attention to this point. A second caveat refers to problems related to the potential endogeneity of the choice of exchange rate regime. Here, we take the exchange rate regime as given when interpreting the results and comparing relative real exchange rate variability under fixed and floating exchange rate regimes. In reality, it

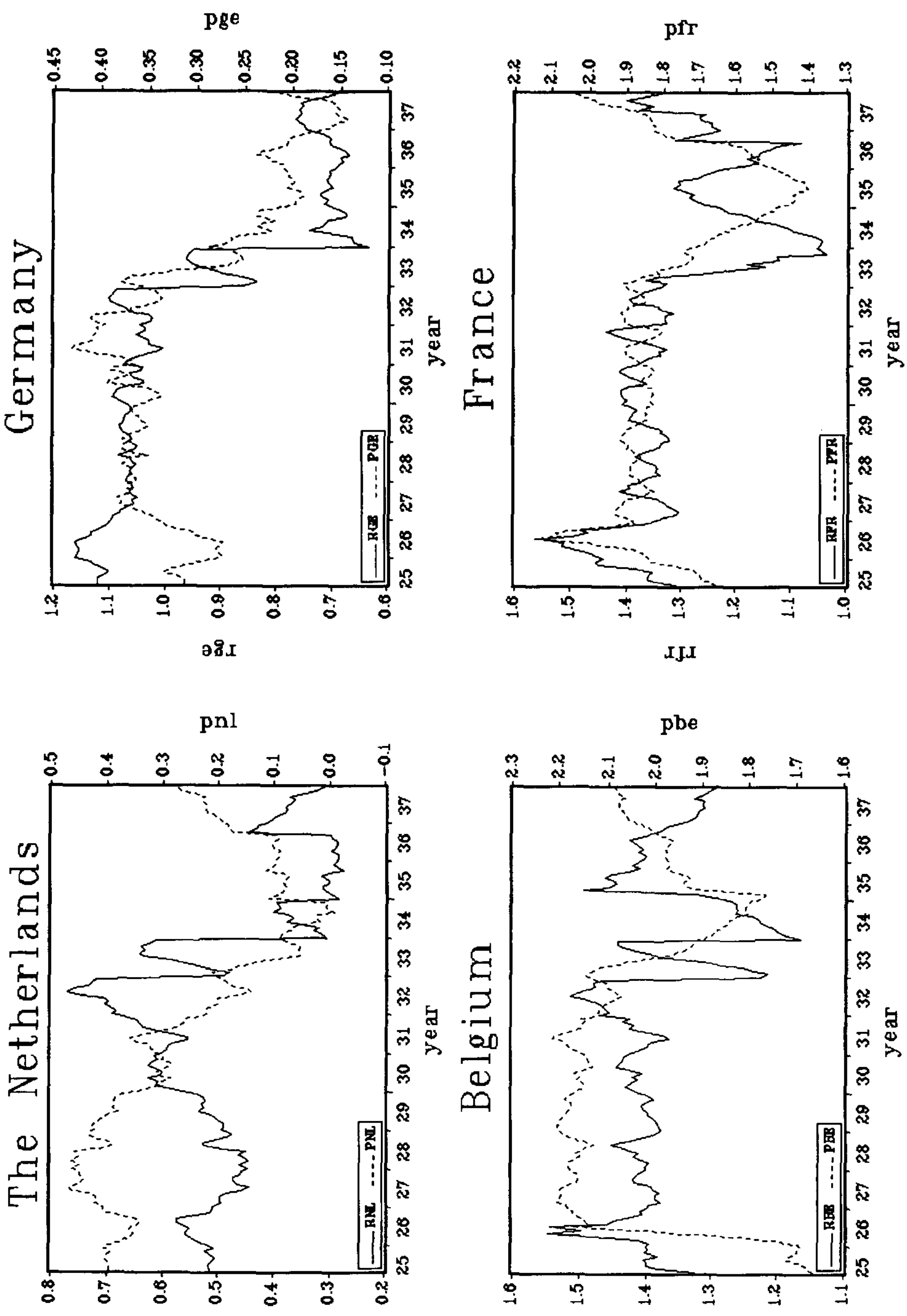

FIGURE 1 — *caption on p. 221.*

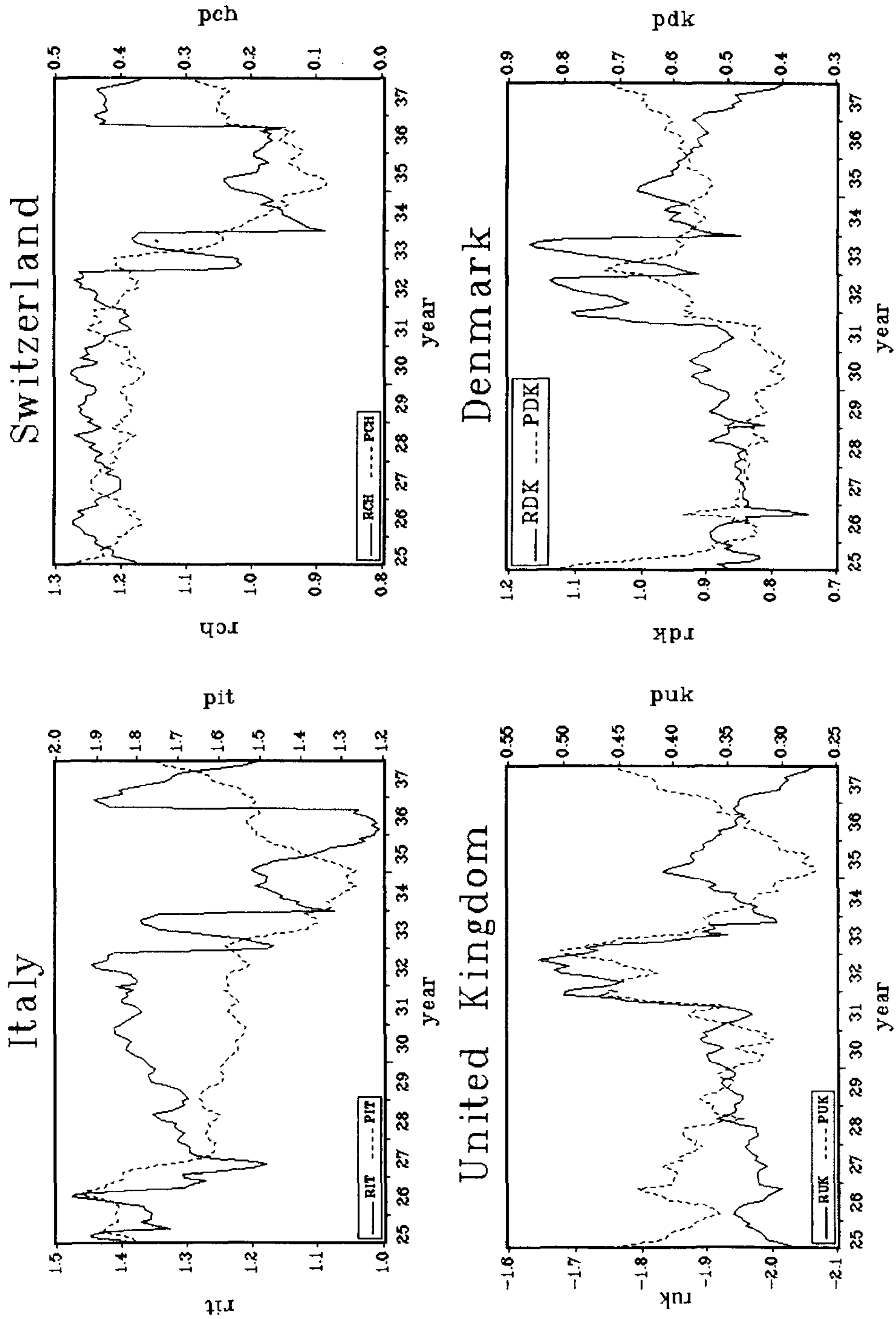

FIGURE 1 — *caption on p. 221.*

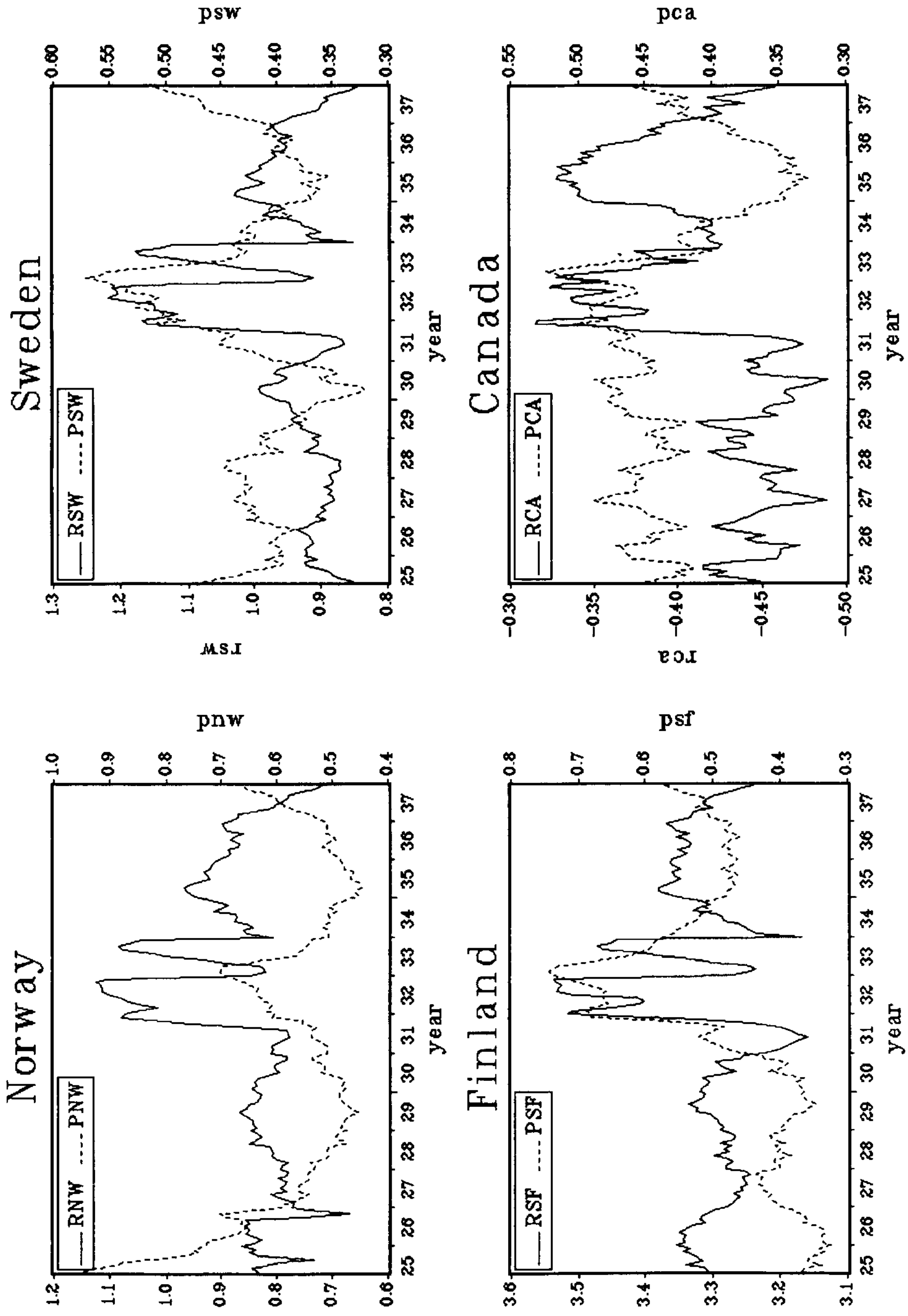

FIGURE 1 — *caption opposite.*

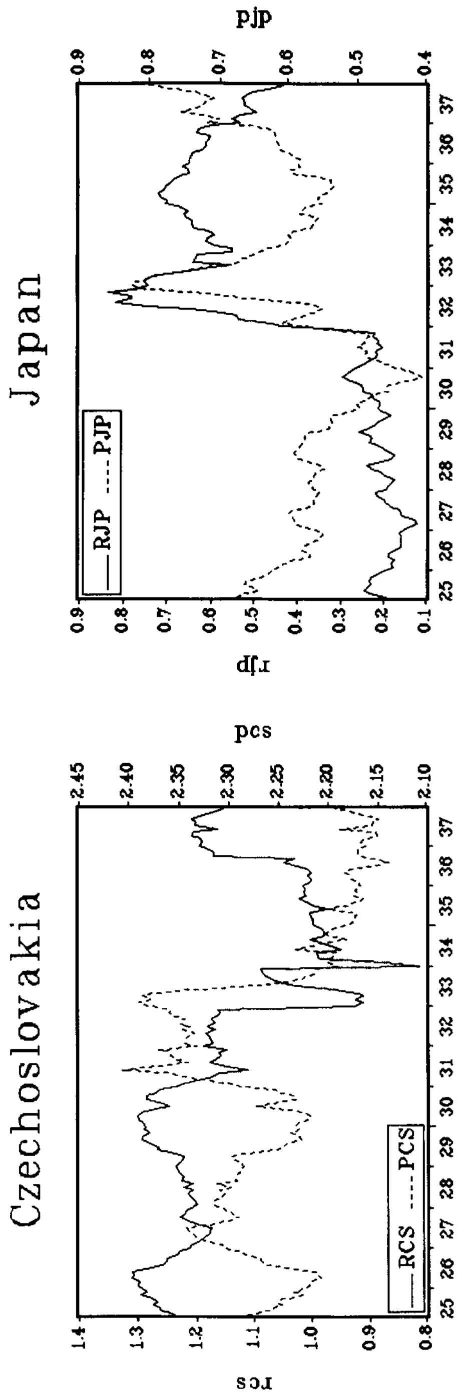

FIGURE 1 (pp. 218–221). Real exchange rates and price differences relative to the US dollar.

may be the case that countries resort to floating rates precisely in times of crises or substantially divergent domestic macroeconomic policies, that is, when the variability of real shocks is high. Solving this issue is beyond the scope of the current paper.[11] For a more detailed overview of the historic events and actually implemented country-specific policies, we refer to Dam (1982) and Eichengreen (1990, 1992).

Table 2 contains the principal component results for both sub periods. In the upper part of the table, the individual and cumulative explanatory power of the first, second, and so forth, component is given, corresponding to equation ⟨13⟩. For instance, the first principal component in the period 1925–1931 explains 33% of total real exchange rate variation. This is computed as the ratio of the first and largest eigenvalue (λ_1) to the sum of all eigenvalues. Similarly, the explanatory power of the second principal component in the first sub period is 24%, which is equal to the ratio of the second largest eigenvalue (λ_2) to the sum of eigenvalues. In the first sub period (1925–1931), six principal components are needed to explain over 90% of the variation in real exchange rates, while in the second period (1931–1937) four principal components are sufficient.[12]

The remaining part of the table is divided in blocks, where each block has a country symbol in parentheses in the upper left hand corner, which indicates the benchmark currency. The first block, for instance, is denoted by (US). Entries in this block give the squared correlation of principal components 1–6 (rows) with each country's (columns) real exchange rate relative to the US dollar (benchmark currency) in the first sub period.

The entry in the first row for the column indicated by NL is 35, for example. That is, 35% of the total variation in the bilateral dollar–guilder real exchange rate can be explained by the first principal component alone. Similarly, the second row entry for Belgium is 42, implying that the second principal component explains 42% of the variation in the bilateral dollar–Belgian franc real exchange rate. In both cases, the explained amount of variation in the bilateral real exchange rate under consideration exceeds the average fit of the component (33 and 24%, respectively), as may be inferred from the bottom of the table. Therefore, these entries are printed in bold characters. Our discussion of the results will be focused on these above-average correlations.

Column totals show the cumulated fit of the included principal components, corresponding to equation ⟨14⟩ with $K = 6$ and $K = 4$ respectively, for the two sub periods. Again using the first block of the table where the US is the benchmark currency, it is seen that the amount of bilateral real exchange rate variation explained by the first six principal components together, differs considerably across countries. Only 35% of US–Canadian real exchange rate variation is explained by the total of the first six principal components, for example, even though these same six components account for 91% of total bilateral exchange rate variation. The obvious implication is that real exchange rate variation between Canada and the US was minor (in a relative sense) over this period.

To save space, both first and second sub period results are presented in Table 2, in the following way. In the first block where the US is the benchmark country, all entries refer to the first sub period. In the second block where the Netherlands is the benchmark country, entries to the right of the (blank) column for the Netherlands itself are first period results. Entries to the left (for the US dollar–Dutch guilder exchange rate), however, are second period

TABLE 2. Principal component results (1925:5–1931:8/1931:9–1937:12)

(US)	US	NL	GE	BE	FR	UK	IT	CH	SW	DK	NW	CS	JP	CA	SF
1	—	**35**	**50**	2	12	**34**	12	2	2	25	2	10	**41**	5	**49**
2	—	**40**	**28**	**42**	**69**	0	**65**	7	7	3	2	24	1	0	7
3	—	**17**	1	1	4	**36**	1	**29**	**74**	**20**	5	**34**	1	11	**16**
4	—	0	5	**15**	2	0	**16**	0	2	6	**23**	**18**	**16**	6	**19**
5	—	0	0	5	2	5	1	3	0	**23**	**53**	0	1	**11**	0
6	—	3	3	**13**	5	**10**	1	**12**	1	2	0	**7**	**26**	2	2
Total	—	95	87	78	94	85	96	53	86	79	85	93	86	35	93
(NL)															
1	**57**	—	**81**	**50**	**70**	10	6	**48**	**41**	13	**37**	**67**	2	**36**	**78**
2	**35**	—	5	5	3	**57**	9	**28**	**36**	**42**	23	4	**39**	**34**	9
3	1	—	9	**12**	3	0	**35**	3	3	3	5	1	**15**	**22**	0
4	1	—	1	8	2	0	**26**	0	1	2	7	10	8	0	7
5	—	—	0	5	4	7	4	3	1	**18**	**25**	0	0	0	0
6	—	—	0	**16**	**13**	**20**	**13**	**12**	**9**	**9**	2	**14**	**33**	4	5
Total	94	—	96	96	95	94	93	94	91	87	99	96	97	96	99
(GE)															
1	**56**	7	—	27	4	**66**	**59**	**36**	**45**	**69**	26	12	**70**	**35**	4
2	**32**	8	—	0	**39**	10	21	12	5	8	12	0	7	**31**	7
3	2	4	—	0	4	8	2	8	**32**	5	1	**43**	0	6	**27**
4	0	**34**	—	**29**	**16**	2	7	5	1	0	5	9	1	1	**17**
5	—	—	—	4	4	2	1	1	0	**9**	**39**	0	1	3	0
6	—	—	—	**22**	**21**	**9**	5	**16**	4	5	2	**27**	**18**	**6**	**20**
Total	90	53	—	82	88	97	95	78	87	96	85	91	97	82	75
(BE)															
1	8	43	**46**	—	14	**35**	23	0	7	26	0	4	**34**	0	30
2	6	25	24	—	**41**	**25**	21	**31**	11	17	15	0	14	**37**	5
3	3	4	9	—	5	**14**	2	**13**	**40**	7	1	**28**	0	6	9
4	**36**	**23**	**14**	—	2	**12**	**48**	**21**	**20**	**26**	**47**	**56**	**32**	**22**	**48**
5	—	—	—	—	0	0	0	1	4	3	**17**	3	6	**13**	4
6	—	—	—	—	0	0	1	2	5	3	**8**	0	2	**6**	1
Total	53	95	93	—	62	86	95	68	87	82	88	91	88	84	97
(FR)															
1	24	20	19	6	—	**39**	**49**	11	21	**35**	6	1	**41**	6	8
2	4	**59**	**62**	16	—	**52**	0	**71**	**48**	**46**	**52**	**29**	**39**	**65**	**44**
3	**40**	**13**	12	**56**	—	2	8	0	**12**	0	0	**13**	2	10	2
4	2	3	0	**13**	—	2	**33**	3	6	7	**21**	**42**	**12**	5	**32**
5	—	—	—	—	—	0	0	1	3	1	**11**	4	4	7	4
6	—	—	—	—	—	0	1	1	3	2	5	0	1	3	1
Total	70	95	93	91	—	95	91	87	93	91	95	89	99	96	91

— *continued*

TABLE 2. (*Continued*)

(US)	US	NL	GE	BE	FR	UK	IT	CH	SW	DK	NW	CS	JP	CA	SF
(UK)															
1	6	**65**	**68**	0	6	—	0	**66**	28	2	**34**	**53**	3	**34**	**78**
2	**41**	5	2	19	**79**	—	**63**	3	8	3	1	20	0	1	3
3	**28**	**15**	**13**	**46**	1	—	**17**	4	**16**	5	7	3	**27**	**41**	0
4	1	4	0	**19**	0	—	**17**	0	2	**12**	**17**	**17**	**23**	1	**12**
5	—	—	—	—	—	—	0	1	**8**	**16**	**23**	3	**14**	**12**	2
6	—	—	—	—	—	—	0	0	**7**	**7**	**7**	0	**9**	4	0
Total	76	89	83	84	86	—	97	74	69	45	89	96	76	93	95
(IT)															
1	**79**	0	2	**47**	30	**45**	—	18	7	1	20	**40**	0	17	**59**
2	1	**69**	**47**	1	6	16	—	**51**	**44**	**63**	**55**	21	**74**	**65**	**27**
3	1	8	12	0	**40**	**25**	—	10	**34**	**13**	5	**32**	2	0	11
4	8	7	**21**	**44**	**17**	**11**	—	**18**	11	10	1	1	3	10	0
5	—	—	—	—	—	—	—	0	1	3	**13**	1	4	4	1
6	—	—	—	—	—	—	—	0	0	0	2	1	5	1	0
Total	89	84	82	92	93	97	—	97	97	90	96	96	88	97	98
(CH)															
1	**74**	2	0	**49**	25	30	13	—	14	**38**	0	9	**48**	0	**54**
2	1	**87**	**81**	11	1	**37**	18	—	1	0	0	20	1	8	2
3	1	5	10	0	**63**	**26**	0	—	**44**	0	3	**14**	7	**50**	1
4	1	0	3	**34**	6	2	**26**	—	5	7	**29**	**33**	**15**	4	**29**
5	—	—	—	—	—	—	—	—	4	**11**	**44**	2	5	**15**	3
6	—	—	—	—	—	—	—	—	5	2	**8**	1	**7**	5	0
Total	77	94	94	94	95	95	57	—	73	58	84	79	83	82	89
(SW)															
1	15	**67**	**66**	3	1	2	**49**	33	—	12	6	**35**	22	5	**72**
2	**53**	5	2	**47**	**54**	0	24	**58**	—	1	1	17	2	6	0
3	3	9	**18**	0	**43**	**85**	0	0	—	**22**	**29**	**1**	**40**	**79**	6
4	3	10	1	**27**	0	1	**22**	6	—	1	10	**20**	7	0	**13**
5	—	—	—	—	—	—	—	—	—	**24**	**45**	0	1	2	0
6	—	—	—	—	—	—	—	—	—	0	1	**7**	**15**	0	1
Total	74	91	87	77	98	88	95	97	—	60	92	80	87	92	92
(DK)															
1	9	**73**	**70**	0	3	0	**57**	37	10	—	**37**	**47**	6	24	**76**
2	**70**	3	1	**38**	**52**	0	25	**52**	**1**	—	0	14	0	2	1
3	3	8	**15**	0	**39**	**77**	0	0	0	—	4	7	**12**	**25**	0
4	1	4	0	**30**	0	0	**14**	2	9	—	8	7	5	1	5
5	—	—	—	—	—	—	—	—	—	—	**10**	**12**	**35**	**27**	**10**
6	—	—	—	—	—	—	—	—	—	—	2	3	**19**	0	0
Total	83	88	86	68	94	77	96	91	20	—	61	90	77	79	92

— *continued*

TABLE 2. (*Continued*)

(US)	US	NL	GE	BE	FR	UK	IT	CH	SW	DK	NW	CS	JP	CA	SF
(NW)															
1	11	**66**	**64**	**1**	2	0	**51**	33	9	3	—	5	**36**	0	**39**
2	**57**	3	1	**50**	**53**	1	25	**54**	4	0	—	17	0	2	3
3	4	9	**18**	0	**42**	**89**	0	0	2	1	—	**20**	1	**13**	5
4	4	10	1	**22**	0	2	**22**	6	2	**14**	—	0	0	10	0
5	—	—	—	—	—	—	—	—	—	—	—	**40**	**41**	**69**	**41**
6	—	—	—	—	—	—	—	—	—	—	—	**9**	**17**	1	3
Total	76	88	84	73	97	92	98	93	17	18	—	91	95	95	91
(CS)															
1	**59**	9	6	28	6	12	26	26	11	15	13	—	**56**	5	**47**
2	12	**79**	**80**	**35**	1	**54**	24	15	**83**	**75**	**80**	—	13	**25**	15
3	4	5	10	0	**79**	**30**	0	2	0	0	0	—	**21**	**50**	10
4	1	3	0	**20**	0	0	**32**	**19**	0	0	0	—	1	10	0
5	—	—	—	—	—	—	—	—	—	—	—	—	1	2	0
6	—	—	—	—	—	—	—	—	—	—	—	—	2	4	4
Total	76	96	96	83	86	96	82	62	94	90	93	—	94	96	76
(JP)															
1	39	**87**	**83**	**44**	**53**	**53**	**92**	**85**	**64**	**58**	**58**	**66**	—	**53**	**83**
2	12	6	4	2	14	4	2	9	4	6	5	17	—	1	2
3	0	0	1	1	**15**	**16**	1	1	2	2	2	1	—	6	6
4	**21**	4	10	**52**	**16**	**20**	0	5	**26**	**21**	**28**	**13**	—	7	1
5	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0
6	—	—	—	—	—	—	—	—	—	—	—	—	—	**18**	4
Total	72	97	98	99	98	93	95	100	96	87	93	97	—	85	96
(CA)															
1	7	**68**	**71**	21	38	19	**79**	**77**	31	22	24	**60**	34	—	**39**
2	20	25	22	1	15	**38**	0	6	**41**	**54**	**47**	21	6	—	8
3	**14**	0	0	**13**	**29**	**26**	4	4	12	**14**	**14**	9	1	—	**30**
4	**15**	3	0	**27**	0	1	**13**	4	0	1	0	0	**39**	—	**12**
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
Total	56	96	93	62	82	84	96	91	84	91	85	90	80	—	91

— *continued*

results. The corresponding first period results for the dollar–guilder can already be found in the first block (US benchmark country). In general, for each block (benchmark country), entries to the right of the blank benchmark country column refer to the first sub period, while entries to the left are for the second sub period.

III.A. The gold-exchange standard, May 1925 to August 1931

The formal start of the interwar gold-exchange standard was generally set in May (or April) 1925, because of Britain's return to the gold standard. However,

TABLE 2. (*Continued*)

(US)	US	NL	GE	BE	FR	UK	IT	CH	SW	DK	NW	CS	JP	CA	SF
(SF)															
1	7	**60**	**59**	0	7	0	**67**	**61**	14	1	5	32	**61**	19	—
2	24	18	14	9	**27**	9	5	**27**	**51**	**39**	**50**	**59**	0	11	—
3	11	10	**17**	4	**62**	**81**	1	2	5	3	2	1	5	**31**	—
4	2	4	0	**49**	0	0	**17**	4	1	1	2	0	**29**	0	—
5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Total	44	92	90	62	96	90	90	94	71	44	59	92	95	61	—

[a]Explanatory power of principal components (percentage explained real exchange rate variation)

Component:	1	2	3	4	5	6	Cumulated
1925—31	33	24	11	11	7	5	91
1931—37	32	26	12	10	—	—	91

[b]Entries are squared correlations between principal components and real exchange rates. Individual components are indexed by row number, real exchange rates defined relative to a benchmark currency are indexed by columns. The benchmark currency is indicated between parentheses in the upper left corner of each part of the table. Correlations for 1925:5–1931:8 are in the upper right triangle, while correlations for 1931:9–1937:12 are in the lower left triangle.

it is well-known that many countries took much longer to stabilize their economies and to fix their currencies in terms of gold again. In particular, of the countries in our sample, France, Italy, Belgium, Denmark, Norway and Japan had floating nominal exchange rates for some time after May 1925 before joining the gold standard. Japan was the last one of this group in 1930. In that sense, the first sub period in our analysis provides an interesting opportunity to compare two sources of real exchange rate changes. On the one hand, real exchange rate changes originating from diverging price levels across countries with fixed exchange rates, and on the other hand, real exchange rate changes originating from the countries that remained on (managed) floating exchange rates temporarily.

The first principal component in the period 1925–1931 explains 33% of the total variation in real exchange rates, and is predominantly associated with movements in the real exchange rates of all countries, except Belgium and France, relative to Finland and Germany. This can be seen by checking that the entries at the first row under the column SF (Finland) are mostly printed bold. The explanatory power of the first component to explain bilateral movements in real exchange rates relative to the Finnish markka often exceeds 50%. The same, though to a lesser degree, is true for Germany.

The second principal component explains 24% and mainly is a French–Italian phenomenon. Bilateral exchange rate movements against the French franc or Italian lira are generally highly correlated with this component. The third and fourth component both explain about 11% of exchange rate variation. The third component shows strong correlation with exchange rate movements between Canada and the US on the one hand, and Sweden and Czechoslovakia on the other. It is, however, also explaining movements between the US and Canada and a large group of countries, to wit, the Netherlands, the UK, Switzerland, Denmark and Finland, and between Sweden and Czechoslovakia and another group, Germany, Belgium, Italy, Switzerland, Denmark, Norway and Japan. The fourth component is a pure Belgian phenomenon.

The fifth component, explaining 7% is representing movements against Norway and Denmark. Finally, the sixth component is a mix, again. Predominantly, it explains movements in the Japanese yen relative to the Netherlands, Germany, Belgium, the UK, Sweden, Denmark, Norway, the US and Canada. However, the sixth component is also significantly correlated with movements in the Dutch guilder and German mark relative to Belgium, France, the UK, Italy, Switzerland, Sweden, Denmark and Czechoslovakia.

The above split-up of the total amount of exchange rate variation in independent factors and the identification of specific countries with each factor lead to the following conclusions. The first principal component is primarily a Finnish–German phenomenon. As both countries have been on the gold standard over the whole sample, this suggests that the principal source of real exchange rate variation in the period 1925–1931, was due to price divergences across countries. A similar argument holds for the third component where the US, Canada, Sweden and Czechoslovakia play a dominant role. The US and Sweden were on the gold standard from the beginning of the sample, while Canada and Czechoslovakia followed soon.

For the other four principal components identified, a different story holds: the real exchange rate variation identified in prinicpal components 2, 4, 5, and 6 apparently is due more to the adjustment of individual countries under floating nominal exchange rates.

Overall, then, about half of the identified real exchange rate variation in the period 1925–1931 may be assigned to nominal exchange rate adjustment and half of it to cross-country price level divergences.

III.B. Managed floating, September 1931 to December 1937

The start of the second sub period is September 1931, when the UK was driven off the gold standard. The response of other countries was mixed. For this period, a grouping of countries in a ‘sterling bloc’ and a ‘gold bloc’ (according to the prevailing exchange rate regime) is fairly standard in the literature. Dam (1982, p. 48) for example, states that ‘the world was effectively divided into monetary blocs. European countries adhering to the gold standard had formed a “gold bloc” upon the collapse of the 1933 World Economic Conference.[13] Although the governments of France, Belgium, Italy, the Netherlands, Poland, and Switzerland agreed that their central banks should cooperate to maintain the existing gold parities, the gold bloc was little more than a name for those European countries remaining on gold. A second regional group was the sterling area, whose members tended to float with sterling.’ According to

Nurkse (1944, p. 47) the sterling area comprised 'in the first instance the British Commonwealth of Nations, with the important exception of Canada, whose currency took a middle course between the pound and the US dollar. ... Others joined it later: the Scandinavian countries, for example, in 1933. ... In addition, there were several countries, including Japan and Argentina, which kept their official exchange rate fixed in sterling, but which were not generally regarded as members of the sterling bloc.'[14]

In this paper, we take the European gold-bloc to consist of France, Switzerland, the Netherlands, and Belgium. The US is not included in this group although they remained on gold most of this period. The US suspended the gold standard in April 1933 and after a devaluation and a short period of managed floating again stabilized the dollar against gold in January 1934. However, Dam (1982, p. 48) argues that 'the gold bloc countries were substantially overvalued relative not just to sterling area currencies but to the dollar as well'. Therefore, the US gold standard is assumed to differ from the European gold bloc. Czechoslovakia and Italy originally belonged to the European gold bloc as well, but switched to a group of countries, including Germany, that used strict exchange controls to fix their exchange rate. They thus take an intermediate position. The sterling-bloc is assumed to consist of the UK, Denmark, Norway, Sweden and Finland. Because Japan informally fixed to the pound sterling it is considered a potential sterling bloc member as well. Canada tried to steer a course between the UK (within the Commonwealth) and the US, its main trading partner. Thus, Canada is thought to have a position between the sterling area on the one hand and the US gold standard on the other.

The results of the principal components analysis for this period are in the lower left triangle in Table 2. The first principal component explains 43% of total real exchange rate variation and is primarly correlated with real exchange rate movements of the US, Canada and Japan on the one hand, and the Netherlands, Germany, Italy, Switzerland and Czechoslovakia on the other. In addition, this first component strongly correlates with movements between the sterling bloc (the UK, Denmark, Norway, Sweden and Finland), and Japan, the Netherlands, Germany and Italy.

The second component, explaining 26%, predominantly explains exchange rate movements between the sterling bloc (excluding Finland) plus Germany and the Netherlands on the one hand, and the gold-bloc countries the US (+Canada), France, Italy, Switzerland, Belgium and Czechoslovakia on the other.

The third component picks up the movement of the UK relative to the Scandinavian sterling-bloc countries. This reflects a round of competitive devaluations during the transition period 1931–1933 between the suspension of gold in the UK and the formal establishment of the sterling-bloc in 1933. In this period, the Scandinavian countries, at different times and speed, first appreciated due to the devaluation of sterling and then devalued themselves to fix new sterling exchange rates at lower levels than those under the gold standard. The third component is also correlated with the exchange rate movement of France against Belgium, Switzerland and Czechoslovakia within the gold-bloc. The fourth component is largely a Belgian phenomenon and explains about 10%. It also captures exchange rate movements against Japan and Italy.

Overall, the results of our analysis lead to a grouping of countries on the basis of real exchange rate variation that is coinciding with a grouping on the basis of nominal exchange rate regime. The sterling-bloc, the European gold-bloc and the US–Canada gold-bloc[15] can clearly be distinguished in our results. Real exchange rate variation between groups of countries with different nominal exchange rate regimes (components 1 and 2) appear to be dominating real exchange rate variation within blocs (components 3 and 4, and partly 2). Moreover, a considerable part of the within bloc variation is due to competitive devaluations within the sterling bloc, which may be interpreted as a form of managed nominal floating. The results support earlier evidence, that real exchange rate variation to a large extent depends on the nominal exchange rate regime.[16]

IV. Summary and conclusion

In this paper, we have constructed a new data set of real exchange rates for 15 countries over the period May 1925 to December 1937, covering both the interwar gold-exchange period and managed float period. We have applied a modified principal component technique to analyze patterns in real exchange rate behavior under different nominal exchange rate regimes.

The modification of the principal components technique consists of a linear transformation such that the choice of an arbitrary benchmark currency does not affect the results. This allows for a symmetric treatment of all bilateral real exchange rates, and improves on most applied work that focuses on real exchange rates expressed in either US dollars or UK pounds only.

The evidence for the period May 1925–August 1931 suggests that about half of the total real exchange rate variation in that period derives from price level divergences, while the other half originates from countries on floating nominal exchange rates during part of the period to stabilize their economies. It shows that cross-country price level differences can be important for real exchange rates. No evidence is found, though, of dominant real exchange rate movements due to the often claimed overvaluation of the British pound in that period.

The second period results (September 1931–December 1937) show that an ordering of countries on the basis of real exchange rate movements is approximately coinciding with an ordering on the basis of countries' nominal exchange rate regime. The two most dominant principal components are associated with real exchange rate movements between the European gold-bloc countries, the US and Canada, and the Sterling bloc. Real exchange rate movements within blocs appear of secondary importance only. Moreover, part of the within bloc variation may also be interpreted as being due to managed nominal exchange rate variability (competitive devaluations).

Because the principal components analysis allows for a symmetric treatment of all bilateral exchange rates, we are able to go beyond earlier evidence by, among others, Eichengreen (1988, 1990, 1992) that the nominal exchange rate regime has heavily influenced real exchange rate behavior in the interwar period. We are able to identify a few common factors behind real exchange rate variability that correspond closely to a standard grouping of countries with similar exchange rate policies. Floating nominal exchange rates between these groups (blocs) appear to be the largest source of real exchange rate movements in the 1930s.

Our evidence throws doubt on the hypothesis put forward by Grilli and Kaminsky (1991) that the degree of correspondence between real exchange rate variability and nominal exchange rate regime depends on random sample-specific events. Our finding that nominal and real exchange rate variability are closely linked is consistent both with Mussa's argument based on sticky goods prices in a Dornbusch-type exchange rate model and with models of destabilizing speculation. Also, it may be possible that the choice of exchange rate regime itself is endogenous and is determined by the relative frequency of cross-country shocks, so that reverse causality leads to our findings. We are unable to solve this issue satisfactorily. However, since Eichengreen (1993) concludes that monocausal explanations are unlikely to provide a full account of the endogeneity of exchange rate regimes, some confidence may be attached to the underlying assumption here that the exchange rate regime is at least weakly exogenous to real exchange rate shocks.

Notes

1. For recent evidence on the mean reversion of real exchange rates under the gold standard and the recent float, we refer to Diebold et al. (1991), and Lothian and Taylor (1996). Fisher (1934) contains early work on this issue.
2. We refer to de Grauwe et al. (1985) for a comparison of real exchange rate variability under floating exchange rates in the 1920s and 1970s.
3. See Koedijk and Schotman (1989) and Koedijk and Kool (1992) for application of this technique in the fields of exchange rates and interest and inflation differentials, respectively.
4. See Stock and Watson (1988) for the connection between principal components and cointegration analysis.
5. B is unique apart from sign, if all elements of Λ are different, which we henceforth assume.
6. For notational convenience, the subscript on ι and I will be suppressed when there can be no confusion about the appropriate dimensions.
7. In a maximum likelihood derivation of the principal components, θ has the interpretation of a variance. The choice of θ does not affect the factor loadings; it only serves as a scalar scaling parameter for all time series of principal components.
8. The alternative solution is $\alpha = (1 + (n+1)^{-1/2})/n$. Which of the two solutions for α is chosen is irrelevant, since the principal components depend on Q, not $Q^{1/2}$.
9. Tinbergen (1934) has served as an additional data source.
10. The rise in real exchange rate variation (relative to the £) for countries in the sterling-bloc (see Table 1), is completely due to the transition in the years 1931–1933 from the gold standard to a sterling-link. This illustrates the care with which summary statistics should be interpreted.
11. Eichengreen (1993) elaborates on this issue.
12. Anderson (1984) suggests to ignore the last $p - m$ principal components (where p is the number of variables included), if their cumulative explanatory power is small relative to the overall variance. We follow this suggestion, using a 10% threshold.

Coincidentally, in our application it implies that no principal components with an individual explanatory power of at least 5% are left out of the analysis.

13. The World Economic Conference refers to the negotiations about a stabilization arrangement among the United States, Britain, and the countries that had remained on the gold standard after September 1931.
14. See Dam (1982), Nurkse (1944), and Eichengreen (1988, 1990, 1992) for a more detailed account of this period.
15. As a side result, our analysis shows that Canada kept much closer to the US than to the UK in the second period. According to Table 2, the first four components together explain 84% of Canada's real exchange rate variability relative to the pound, but only 56% of variability relative to the US dollar.
16. Eichengreen and Irwin (1993) provide an interesting link between trade blocs and currency blocs in the 1930s. In general, currency blocs appear to have had a positive effect of intra-bloc trade relative to trade with the rest of the world. This raises important questions with respect to the relation and causality between trade flows and real exchange rates. These are left for future research, however.

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